



# *United Kingdom of Great Britain and Northern Ireland*

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BS NA EN 1993-3-1 (2006) (English): UK National  
Annex to Eurocode 3. Design of steel structures.  
Towers, masts and chimneys. Towers and masts

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*We will sell to no man, we will not deny or defer to any man either Justice or Right.*  
MAGNA CARTA (1297)

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NA to BS EN 1993-3-1:2006



BSI Standards Publication

# **UK National Annex to Eurocode 3: Design of steel structures**

Part 3-1: Towers, masts and chimneys —  
Towers and masts

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### Summary of pages

This document comprises a front cover, an inside front cover, pages 1 to 22, an inside back cover and a back cover.

# National Annex NA (informative) to BS EN 1993-3-1:2006, Eurocode 3 – Design of steel structures – Part 3-1: Towers, masts and chimneys – Towers and masts

## Introduction

This National Annex has been prepared by BSI Subcommittee B/525/32, *Towers and masts*. It is to be used in conjunction with BS EN 1993-3-1:2006+C1:2009.

The content of this National Annex to BS EN 1993-3-1 is critically dependent on the content and formulation for wind actions in the National Annex to BS EN 1991-1-4, *Wind actions*, which was published in October 2008. However, there has been no National Calibration Period, as envisaged in Guidance Paper L [1], and the co-existence period before withdrawal of the National Standard (BS 8100) has been curtailed from the minimum three years specified in Guidance Paper L [1]. Therefore, no calibration studies have yet been undertaken on BS EN 1993-3-1 and its National Annex. It is therefore strongly recommended that, in using these documents, design is undertaken using recognized documents in parallel with these.

It is an assumption of this NA that all structures will be maintained in accordance with the minimum requirements of their designers. Recommended content for a maintenance manual providing this information is given in PD 6695-3-1 (in preparation).

## NA.1 Scope

This National Annex gives:

- a) the UK decisions for the Nationally Determined Parameters described in the following subclauses of BS EN 1993-3-1:2006:
- |                  |                    |                    |
|------------------|--------------------|--------------------|
| — 2.1.1(3)P Note | — 6.4.2(2)         | — B.4.3.2.8.1(4)   |
| — 2.3.1(1)       | — 6.5.1(1)         | — C.2(1)           |
| — 2.3.2(1)       | — 7.1(1)           | — C.6(1)           |
| — 2.3.6(2)       | — 9.5(1)           | — D.1.1(1)         |
| — 2.3.7(1)       | — A.1(1)           | — D.1.2(2)         |
| — 2.3.7(4)       | — A.2(1) (2 times) | — D.3(6) (2 times) |
| — 2.5(1)         | — B.1.1(1)         | — D.4.1(1)         |
| — 2.6(1)         | — B.2.1.1(5)       | — D.4.2(3)         |
| — 4.1(1)         | — B.2.3(1)         | — D.4.3(1)         |
| — 4.2(1)         | — B.2.3(3)         | — D.4.4 (1)        |
| — 5.1(6)         | — B.3.2.2.6(4)     | — F.4.2.1(1)       |
| — 5.2.4(1)       | — B.3.3(1)         | — F.4.2.2(2)       |
| — 6.1 (1)        | — B.3.3(2)         | — G.1(3)           |
| — 6.3.1(1)       | — B.4.3.2.2(2)     | — H.2(5)           |
| — 6.4.1(1)       | — B.4.3.2.3(1)     | — H.2(7)           |

- b) the UK decisions on the status of BS EN 1993-3-1:2006 informative annexes B, C, E, F, G and H (see **NA.3**); and
- c) references to non-contradictory complementary information (see **NA.4**).

## NA.2 Nationally determined parameters

### NA.2.1 Guy rupture [BS EN 1993-3-1:2006, 2.1.1(3)P Note]

The procedure recommended in BS EN 1993-3-1:2006, Annex E, should be used.

### NA.2.2 How BS EN 1991-1-4 should be supplemented for masts and towers [BS EN 1993-3-1:2006, 2.3.1(1) Note]

The procedure recommended in BS EN 1993-3-1:2006, Annex B, should be used, with the following modifications.

BS EN 1993-3-1:2006, Annex B, makes reference to BS EN 1991-1-4 for parameters to define the wind structure to be used. The formulation in the UK National Annex to BS EN 1991-1-4 modifies the parameter to define peak pressures by adopting a "peak factor" of 3,0 with a quadratic equation, rather than 3,5 with a linear equation, as used in BS EN 1991-1-4. The decision to change the formulation was due to the use of the ten minute wind speed in BS EN 1991-1-4 and the greater accuracy in the quadratic expression.

As a consequence of this, equations B14a, B14b, B15, B16, B17, B22, B23, B24 and B25 in Annex B need to be amended as follows for use in the UK, for which the National Annex to BS EN 1991-1-4 is required.

Replace  $1 + 7I_v(z)$  in each of equations B14a to B17 and B22 to B25 with  $[1 + 3,0I_v(z)]^2$ .

The value of  $k_s$  in BS EN 1993-3-1:2006, **B.4.4(2)** (spectral analysis method only), may be taken as 2,95.

The scope of BS EN 1991-1-4 is limited to 200 m in height, and the wind structure parameters  $c_r(z)$ ,  $c_{r,T}$ ,  $I_v(z)_{flat}$ ,  $k_{l,T}$ ,  $c_e(z)$ ,  $c_{e,T}$  given in Figures NA.3 to NA.8, respectively, of the National Annex to BS EN 1991-1-4 are only provided up to 200 m.

For the design of towers and masts taller than 200 m the values for these parameters are given on the IStructE website at <http://www.istructe.org/eurocodes/windukdata.asp> (see Annex A.NA.1.2).

### NA.2.3 Ice loading [BS EN 1993-3-1:2006, 2.3.2(1)]

The procedure recommended in BS EN 1993-3-1:2006, Annex C, should be used, augmented by the data given in **NA.2.33**.



**NA.2.4 Imposed loading [BS EN 1993-3-1:2006, 2.3.6(2)]**

The following minimum characteristic imposed loads on ladders, platforms and railing should be used.

- a) The ladder, modified bracing, or any component thereof, should be designed to withstand the following simultaneous loads between supports, and should not deflect more than 10 mm or 1/200 of the span, whichever is smaller:
  - 1) 1,5 kN load acting vertically downwards;
  - 2) 0,5 kN point load acting horizontally.

Where critical on a longer ladder run, the loading should be considered to apply at a minimum interval of 5 m.

- b) Platform and walkway flooring should be designed to withstand the following loads simultaneously and should not deflect more than 10 mm or 1/200 of the span, whichever is smaller:
  - 1) 1,5 kN load over a square of 150 mm side acting vertically downwards;
  - 2) 1,5 kN/m<sup>2</sup> distributed load acting vertically downwards.
- c) Platform and walkway hand railings should be designed to withstand the following loads simultaneously and should not deflect laterally more than 15mm:
  - 1) 1,5 kN point load acting vertically downwards;
  - 2) 0,75 kN point load acting horizontally.
- d) All imposed loads due to access requirements should be deemed to apply with a mean wind speed of 10 m/s and no ice loading.

**NA.2.5 Accidental and other actions  
[BS EN 1993-3-1:2006, 2.3.7]**

The possibility of explosions, vandal damage and fire should be considered in design. Guy rupture should be considered for guyed masts of high reliability. Advice is provided in BS EN 1993-3-1:2006, 2.1.1(3)P.

**NA.2.6 Actions arising from fitting safety access equipment  
[BS EN 1993-3-1:2006, 2.3.7(4)]**

It is an assumption of this National Annex that a suitable method of safe access, commensurate with the through-life operation and maintenance of the structure, has been considered by the designer and recorded in the maintenance manual. Where this includes the use of designated anchor points [BS EN 795] their location and use should be clearly specified. Where safe access requires the use of anchorage points [BS EN 365] their operation and use should be specified and their effects on the structure considered.

Particular areas that might be unsuitable for use as a fall arrest hard point include:

- handrails;
- redundant bracing;
- some designs of ladder.

**NA.2.7 Structures subject to an agreed full-scale testing programme [BS EN 1993-3-1:2006, 2.5(1)]**

No additional information is provided.

**NA.2.8 Design service life [BS EN 1993-3-1:2006, 2.6(1)]**

For the purposes of BS EN 1993-3-1, the service life,  $T$ , in years, is taken as the intended period of service of the structure and should be set down in the project specification. A structure designed in accordance with BS EN 1993-3-1 might, if adequately maintained, provide consistent reliability beyond the period of its service life. However, the fatigue life could limit the period of reliable service.

**NA.2.9 Allowance for corrosion [BS EN 1993-3-1:2006, 4.1(1)]**

No further information is provided.

**NA.2.10 Corrosion protection of guys [BS EN 1993-3-1:2006, 4.2(1) Note]**

The guidance given in the Note to BS EN 1993-3-1:2006, 4.2(1), should be used.

**NA.2.11 Global analysis of masts or guyed chimneys [BS EN 1993-3-1:2006, 5.1(6)]**

No further information is deemed necessary for global analysis of masts or guyed chimneys.

**NA.2.12 Continuity in triangulated structures [BS EN 1993-3-1:2006, 5.2.4(1)]**

No additional information is provided.

**NA.2.13 Partial factors on resistance [BS EN 1993-3-1:2006, 6.1(1)]**

The following partial factors on resistance should be used:

Resistance of member to yielding	$\gamma_{MO} = 1,00$
Resistance of member to buckling	$\gamma_{M1} = 1,00$
Resistance of net tension at bolt holes	$\gamma_{M2} = 1,25$
Resistance of guys and their terminations	$\gamma_{Mg} = 2,00$
Resistance of insulating material	$\gamma_{Mi} = 2,50$ .

The factor  $\gamma_{Mg}$  applies to the guy and its socket (or other termination). The factor  $\gamma_{Mi}$  applies to the ceramic insulating material only. The associated steel pins, linkages and plates are designed for compatibility with the guy and its socket, and might require enhanced values of  $\gamma_{MO}$  and  $\gamma_{M2}$ . Values of  $\gamma_{MO} = 1,4$  and  $\gamma_{M2} = 1,75$  should be used.

*NOTE 1 For structures or elements that are to be type-tested, or where similar configurations have previously been type-tested, the partial factors,  $\gamma_M$ , may be reduced, subject to the outcome of the testing programme.*



*NOTE 2 These partial factors for actions and resistance might not be appropriate for the assessment of existing structures. Consideration needs to be given to the design, detailing, fabrication and maintenance of such structures in applying BS EN 1993-3-1 and this National Annex. Such factors need to be agreed between the client, the designer and the competent authority.*

#### **NA.2.14 Compression members [BS EN 1993-3-1:2006, 6.3(1)]**

Compression members in lattice towers and masts should be designed using the procedure given in BS EN 1993-3-1:2006, Annex G and Annex H.

#### **NA.2.15 Partial factors for connections in towers and masts [BS EN 1993-3-1:2006, 6.4.1(1) Note]**

The partial factors for connections recommended in BS EN 1993-1-8:2005, Table 2.1, as modified by the UK National Annex, should be used for towers and masts.

#### **NA.2.16 Flange connections of circular hollow sections [BS EN 1993-3-1:2006, 6.4.2(2)]**

**NA.2.16.1** The following procedure may be used for the design of flange connections of circular hollow sections.

- a) The relationships between flange thickness, expressed as a ratio of tube wall thickness, bolt prying factor, and extent to which the tube is loaded in tension, are shown in Table NA.1.  
  
For the required tube design tensile strength expressed as a proportion of its maximum tensile capacity, the combination of bolt prying factor along the line in the table and flange thickness ratio above this value should be provided as a minimum.
- b) Divide the tensile design strength of the bolts by the bolt prying factor shown in Table NA.1 to determine the direct tension capacity of the bolt.
- c) The pitch circle diameter of the bolts is to be as small as practicable.
- d) The "edge" distance between the flange edge and pitch circle diameter ought not normally to be less than 1,25 times the bolt diameter.

This procedure is generally applicable to flanges in full contact bearing.

*NOTE 1 It might be necessary to increase the minimum thickness to allow for machining to compensate for welding distortion, particularly in the case of blank flanges where a seal or snug fit is required.*



*NOTE 2 This procedure is not appropriate for tube diameters greater than 200 mm.*

*NOTE 3 For flanges where direct contact bearing is required, the flatness is to be such that when measured against a straight edge laid against the full length of the bearing surface in any direction:*

- over at least 50% of the length, the gap measured does not exceed 0,25 mm;
- over at least 90% of the length, the gap measured does not exceed 0,75 mm.

**NA.2.16.2** For the design of flange connections of solid circular members and of tubular members of diameter greater than 200 mm, due account should be taken of the stress pattern under combined axial load, shear and bending, including the effect of prying action. No specific rules are provided and design should be undertaken from first principles, ensuring the general provisions of BS EN 1993 are satisfied.

Table NA.1 Relationships between flange, tube and bolts

Ratio of flange to tube wall thickness <sup>A)</sup> for						
Blank flanges 	2,0	1,9	1,8	1,7	1,6	1,5
Ring flanges 	3,0	2,8	2,6	2,4	2,2	2,0
Ratio of tensile design strength required to maximum tensile capacity of tube <sup>B)</sup>	Increase in direct tension to allow for prying in the flange bolts (bolts prying factor)					
1,0	1,2					
0,9	1,1	1,2				
0,8	1,0	1,1	1,2			
0,7	1,0	1,0	1,1	1,2		
0,6	1,0	1,0	1,0	1,1	1,2	
0,5	1,0	1,0	1,0	1,0	1,1	1,2

Do not use in shaded zone

<sup>A)</sup> Where different grades of steel are used in the tube and flange, the minimum ratio of flange to tube wall thickness should be varied in accordance with the ratio of the square root of their respective yields, within the range shown in the table.

<sup>B)</sup> The relationship between flange thickness ratio and bolt prying factor is a function of the extent to which the tube is loaded in tension.

**NOTE** For flanges not in full contact bearing only the hatched zone of Table NA.1 is to be used.

### NA.2.17 Mast base joints [BS EN 1993-3-1:2006, 6.5.1(1)]

The recommended procedure to allow for eccentricities at the mast base should be used.

### NA.2.18 Partial factors on serviceability and limits [BS EN 1993-3-1:2006, 7.1(1)]

The recommended value of  $\gamma_M$  of 1,0 should be used. The limit of deflection or rotation under the maximum loading from the characteristic wind speed should be as agreed between the designer, the client and the competent authority.

**NOTE 1** The client might need to consider the following.

- The duration of exceedance of such limits. Figure NA.1 provides the number of hours per year for which the mean speed is exceeded, expressed as a fraction of the 0,02 annual probability wind speed.

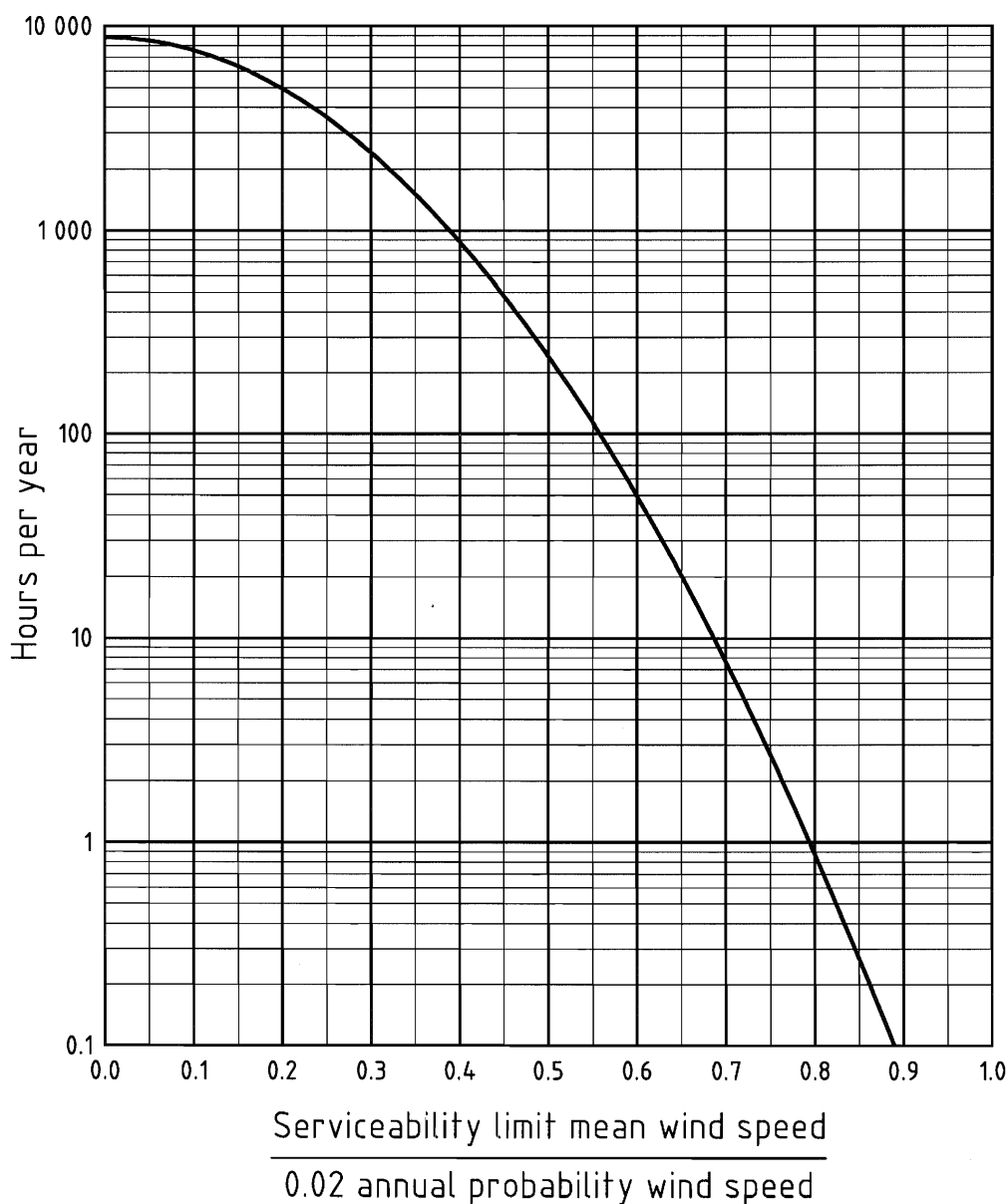
Alternatively, where appropriate records are available the statistical distribution of speeds appropriate to the site may be obtained by analysis of validated wind records obtained in open terrain as near as possible to the site.

- The number of events of such limits.
- Whether steady (ten minute mean) or fluctuating (2–3 second gust) components of wind cause such limits to be critical.

**NOTE 2** Stringent limits might be needed for the use of certain structures (such as for telecommunications, radar, and CCTV or other cameras).

Large single storms at or just below the 0.02 annual probability wind speed can take up to five hours to pass over the site. This should be considered when assessing the fatigue of structures of reliability class 3 or where other serviceability criteria are critical.

Figure NA.1 Hours per year for which the mean wind speed exceeds the serviceability limit



**NOTE** The curve corresponds to a Weibull parent distribution of wind with,  $k$  parameter = 2.

Annual hours exceeded =  $8\,766 / \text{Exp}[(3.79 V / V_{0.02})^2]$ , where  $V_{0.02}$  and  $V$  are calculated at the same location.

#### NA.2.19 Partial factors for fatigue strength [BS EN 1993-3-1:2006, 9.5(1)]

The partial factors for fatigue strength given in Table NA.2 should be used.

Table NA.2 Partial factors for fatigue strength

Partial factor	Reliability class	Value <sup>A)</sup>	
		Damage tolerant	Safe life
$\gamma_{Mf}$	3	1,15	1,35
	2	1,1	1,2
	1	1,0	1,15

**NOTE 1** For definition of "damage tolerant" and "safe life", see BS EN 1993-1-9:2005, Clause 3.

**NOTE 2** All structures have to be inspected in accordance with the minimum requirements specified in their maintenance manual.

**NOTE 3** For existing structures which are subject to safety monitoring the factors in Table NA.2 may be reduced to minimum values of 1,0 for  $\gamma_{Mf}$  for all classes. Such reductions are not to be used unless agreed by the designer, the client and the competent authority.

**NOTE 4** For structures consisting of, supporting or containing prismatic, cylindrical or other bluff elements likely to cause crosswind excitations, enhanced partial factors on loadings might be necessary in view of the uncertainty in the prediction of such response. Such factors have to be agreed between the client, the designer and the competent authority.

A) See BS EN 1993-1-9.

## NA.2.20 Reliability classes [BS EN 1993-3-1:2006, A.1(1)]

The reliability classes given in Table NA.3 should be used.

Table NA.3 Reliability differentiation for towers and masts

Reliability class	Description
3	Towers and masts where the economic or strategic consequences of failure would be likely to be severe.  N.B. This is likely to include most towers and masts located where their failure is likely to cause injury or loss of life.
2	All towers and masts that cannot be defined as Class 1 or 3.  N.B. This might include manned sites or sites adjacent to roads/railways in open countryside, provided the consequences of a failure, especially risk of injury, are likely to be small.
1	Towers and masts, the failure of which would not be likely to cause injury to people, e.g. towers and masts built on unmanned sites in open countryside.

**NOTE** The choice of reliability class (and hence the partial factors in Table NA.4) has to be as agreed between the designer, the client and the competent authority. In assessing existing structures interpolation between the reliability classes, and thus interpolation between the partial factors in Table NA.4, may be used.

### NA.2.21 Partial factors for actions [BS EN 1993-3-1:2006, A.2(1)P Note 2]

The partial factors  $\gamma_G$  and  $\gamma_Q$  given in Table NA.4 should be used.

Table NA.4 Partial factors for permanent and variable actions

Type of effect	Reliability class <sup>A)</sup>	Partial factor	
		Permanent actions	Variable actions
		$\gamma_G$	$\gamma_Q$
Unfavourable	3	1,2	1,6 (see Note 2)
	2	1,1	1,45
	1	1,0	1,3
Favourable	All Classes	1,0	0,0
Accidental situations		1,0	1,0

<sup>A)</sup> See BS EN 1993-3-1:2006, 2.1.2 Note.

**NOTE 1** The partial factor for initial tensions in guys is to be taken as 1,0 throughout.

**NOTE 2** It might be necessary to enhance the partial factor on variable actions for class 3 structures from 1,6 to 1,7 for major structures erected in an urban area where there are occupied buildings within the falling radius.

**NOTE 3** The choice of partial factors has to be agreed between the designer, the client and the competent authority.

### NA.2.22 Use of dynamic response analysis [BS EN 1993-3-1:2006, A.2(1)P Note 3]

Quasi-static analyses should be undertaken under the factored wind load (using the appropriate characteristic load factored by  $\gamma_Q$ ). For guyed masts this implies using the factored mean wind load and applying the patch loads (also factored by  $\gamma_Q$ ).

Dynamic response analyses may be undertaken at the factored mean load position, the dynamic component being added linearly.

### NA.2.23 Ice loading [BS EN 1993-3-1:2006, B.1.1]

Information on ice loading, and combinations of ice with wind, is given in NA.2.33.

### NA.2.24 Information on wind tunnel tests [BS EN 1993-3-1:2006, B.2.1.1(5)]

A separate document on wind tunnel testing is in preparation.

### NA.2.25 Wind force coefficients for individual components [BS EN 1993-3-1:2006, B.2.3 (1)]

The force coefficients given in BS EN 1993-3-1:2006, Table B.2.1, should be used.

**NA.2.26 Reduction factor for ancillary items  
[BS EN 1993-3-1:2006, B.2.3 (3)]**

BS EN 1993-3-1:2006, Table B.2.2, should not be used.

The values of  $K_A$  given in Table NA.5 should be adopted.

Table NA.5 Reduction factor,  $K_A$ , for ancillary items

Position of ancillaries	Reduction factor, $K_A$		
	Ancillaries conforming to BS EN 1993-3-1:2006, B.2.3(2)		Ancillaries not conforming to BS EN 1993-3-1:2006, B.2.3(2), and circular sections in supercritical flow
	Square or rectangular plan form	Triangular plan form	
Internal to the section	0,6	0,5	1,0
External to the section	0,7	0,6	1,0

**NA.2.27 Factor to allow for crosswind turbulence  
[BS EN 1993-3-1:2006, B.3.2.2.6(4)]**

$K_x = 0,5$  should be used.

**NA.2.28 Spectral analysis method  
[BS EN 1993-3-1:2006, B.3.3(1)]**

Spectral analysis methods cannot be codified simply and specialist advice should be sought.

*NOTE* Guidance is provided in PD 6695-3-1. This also applies to BS EN 1993-3-1:2006, B.4.4

**NA.2.29 Parameters for crosswind turbulence  
[BS EN 1993-3-1:2006, B.2.3 (3)]**

Specialist advice should be sought.

**NA.2.30 Scaling factor [BS EN 1993-3-1:2006, B.4.3.2.2 (2)]**

**NA.2.30.1** For each load effect below the top guy level, the value of  $k_s$  may either be taken as 3,5 or a more accurate value of  $k_s$  may be calculated for each load effect (except for cantilevers) in accordance with Annex NA.2.

*NOTE* In BS EN 1993-3-1  $k_s$  is applied to the patch load, not the load effect. For ease of use, the more accurate analysis may be undertaken by carrying out an analysis using patch loads with  $k_s = 3,5$  throughout and then factoring the appropriate fluctuating load effects determined from this analysis by:

$$\left\{ \frac{\text{Values of } k_s \text{ from Annex NA.2}}{3,5} \right\}$$

**NA.2.30.2** For each load effect in cantilevers projecting above the guy level,  $k_s$  should be taken as 3,5.

*NOTE* If the stiffness ratio  $([EI/L \text{ of the cantilever}]/[EI/L \text{ of the mast span immediately below the cantilever}])$  is less than 0,5 then the patch loading procedure might not reflect the dynamic response adequately. Care has thus to be exercised and alternative methods considered, such as an enhanced value of  $k_s$  with the patch loading procedure, or the spectral analysis procedure of BS EN 1993-3-1. These considerations might also be appropriate where there is a large variation of  $EI$  over the height of the cantilever.

**NA.2.31 Loading on guys [BS EN 1993-3-1:2006, B.4.3.2.3(1)]**

The fluctuating tension in the mast guys should be determined using  $k_s = 3,5$ .

**NA.2.32 Factor to allow for crosswind turbulence [BS EN 1993-3-1:2006, B.4.3.2.8.1(4)]**

$K_x = 0,5$  should be used.

**NA.2.33 Ice loads [BS EN 1993-3-1:2006, C.2(1)]**

The following information provides appropriate ice loading to be used.

*NOTE* The information is based on limited data, and local records ought to be studied to ensure that the thicknesses quoted are not likely to be exceeded. Where such records are available statistical analysis ought to be undertaken to derive appropriate characteristic values of ice thickness and density.

**a) Basic ice thickness**

**1) Ice thickness in the absence of wind**

The basic thickness,  $r_b$ , in the absence of wind, should be taken as:

$$r_b = K_i \left( r_o + \frac{\Delta - 200}{25} \right)$$

but not less than  $K_i r_o$

where:

$K_i$  is a coefficient that is either:

- 1,0 for structural section other than round bars, circular tubes, cables or guys; or
- $(\frac{2}{3} + 4/D)$  but not more than 1,2 for round bars, circular tubes, cables or guys, where  $D$  is the diameter of the member (in mm);

$\Delta$  is the altitude of the top of the structure above sea level (in m).

$r_o$  is the radial ice thickness in the absence of wind to be obtained from Figure NA.2 (in mm), appropriate to the position of the site. Alternatively, where data are available  $r_o$  may be derived from a statistical analysis assuming an extremal distribution based on records of the annual maximum thickness of ice formation on components of form and size similar to those to be used in the structure or its attachments



at the latitude and altitude of the site and having an annual probability of occurrence of 0,02.

*NOTE Ice formation is sensitive to the location of the structure within the topography of the site.*

## 2) Ice thickness in conjunction with wind

The basic ice thickness,  $r_b$ , in conjunction with wind, should be taken as:

$$r_b = K_i \left( r_w + \frac{\Delta - 200}{25} \right)$$

but not less than  $K_i r_w$

where:

$K_i$  and  $\Delta$  are as defined in item a)1).

$r_w$  is the radial ice thickness in conjunction with wind to be obtained from Figure NA.2 (in mm), appropriate to the position of the site; alternatively,  $r_w$  may be derived from records [see item a)], but should have an annual probability of occurrence of 0,5.

## b) Reference ice thickness

The reference ice thickness,  $r_r$ , to be considered for design should be taken as

$$r_r = \gamma_Q K_G r_b$$

where:

$\gamma_Q$  is the partial safety factor appropriate to the type of mast.

$r_b$  is the basic radial ice thickness determined in accordance with item a).

$K_G$  is a guy or cable factor which should be taken as either:

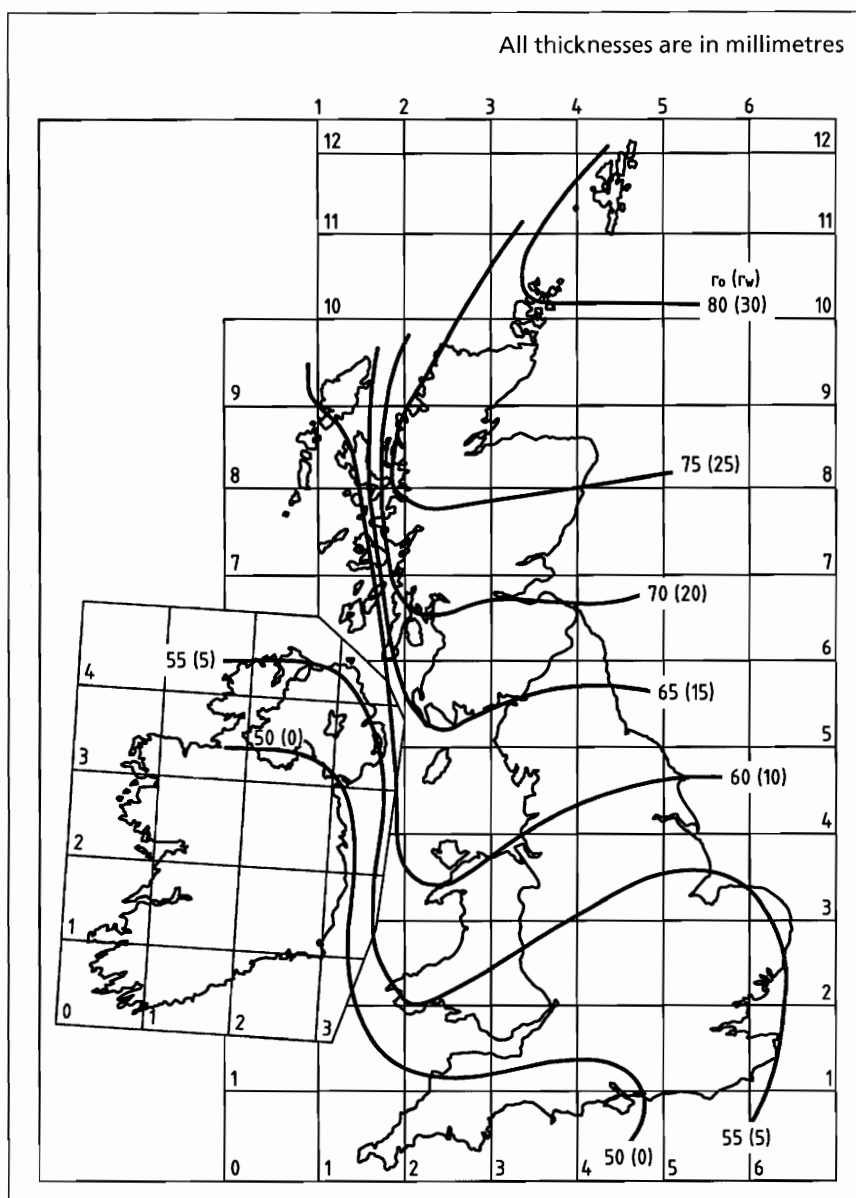
- 1,0 for all tower and mast members, guys and ancillaries; or
- $(N_G + 0,3)/1,3N_G$  for any multiple guys or cables supported by the structure in parallel formation.

$N_G$  is the number of guys or cables.

## c) Ice weight

The weight of ice deposited on the structure should be calculated assuming that all structural sections and ancillary parts are uniformly coated in ice of thickness  $r_r$  and that the following apply.

- 1) The unit weight of ice in the absence of wind is taken as 5 kN/m<sup>3</sup>.
- 2) The unit weight of ice in conjunction with wind is taken as:
  - i) 9 kN/m<sup>3</sup> for design against compression or where its application to guys increases their tension;
  - ii) 5 kN/m<sup>3</sup> for design against tension.
- 3) The weight of ice deposited includes an allowance for gaps of less than 75 mm to be completely filled with ice in accordance with BS EN 1993-3-1:2006, B.2.6.

Figure NA.2 Ice thickness  $r_o$  and  $r_w$ **NA.2.34 Combination factors [BS EN 1993-3-1:2006, C.6(1)]**

The following combination factors should be used.

- a) For dominant ice and accompanying wind:

$$\psi_w = 0,0$$

*NOTE* This implies ice in the absence of wind using reference ice thicknesses from NA.2.33, item b), based on the basic ice thickness from NA.2.33, item a).

- b) For dominant wind and accompanying ice:

$$\psi_w = 0,5$$

$$\psi_{ice} = 1,0$$

$$k = 1,0$$

*NOTE* This implies reduced ice thickness with wind using reference ice thickness from NA.2.33, item b), based on the basic ice thickness from NA.2.33, item a)2).

*NOTE 1 The combination factor  $\psi_w$  implies an effective wind speed of  $\sqrt{0,5} = 0,71$  times the characteristic wind speed.*

*NOTE 2 Local records ought to be studied to try to ascertain the extremes of asymmetric icing and wind speeds in combination, as the specified values are based on limited data.*

### NA.2.35 **Metallic guys and tension elements** **[BS EN 1993-3-1:2006, D.1.1(1)]**

- a) The following additional general rules should be followed.
  - 1) Each guy assembly should incorporate a linkage system to enable both coarse and fine adjustments to be made to the length (or the tension) and to facilitate installation or replacement.
  - 2) Due consideration should be given to lateral movements of the guy in service when sizing link plates and pins, and in the design of attachments to the mast.
  - 3) Where prying action is possible, only a bolt or pin with a lock nut or appropriate locking device should be used to make the connection.
  - 4) Guy link plates should be sized to provide reasonable lateral stiffness.
  - 5) The guy anchor strap should be designed to prevent possible lateral flexing and cracking of concrete anchorages due to lateral movement induced by the guy.
- b) Anchorages should be designed such that all of the following conditions are satisfied.
  - 1) Facilities are available for providing adequate adjustment of guy length to meet the requirement of the maintenance manual in regard to the specified initial load, geometrical tolerances, etc., both on original installation and subsequently.
  - 2) The strand entry to the termination is sealed to prevent the ingress of moisture.
  - 3) Bending of the strand due to transverse wind load or vibrations is minimized, for example, by the use of universal joints (cross-pinned).
  - 4) Articulation is provided in the anchorage details to cater for manufacturing and erection imperfections.
  - 5) All critical welding of the anchorages is subject to non-destructive testing. This normally requires special weld detail designs.

*NOTE The enhanced requirements for guy assemblies and anchorages provide for the wider strength variation and inspection difficulties in this area, as well as the more dynamic nature of the loads.*

- 6) Terminations for guys and their bearing elements within the structure should be proportioned such that their load carrying capacity and the fatigue resistance are compatible with that of the actual guy.

- 7) Terminations provided by sockets attached to the ends of the strands may be assumed to satisfy the requirements of items b)1) to b)5) provided that they meet the following criteria:
- the socket and filler materials conform to BS EN 1993-1-9;
  - the wires of the strands are separated and splayed out within the length of the socket chamber to fill the cone in uniform manner;
  - the ultimate limit state verification specified in BS EN 1993-3-1:2006, 6.1, is satisfied;
  - proper alignment of the strand in the socket is obtained.

**NA.2.36 Non-metallic guys [BS EN 1993-3-1:2006, D.1.2(2)]**

The following additional information should be followed.

- a) In the case of synthetic materials that are proprietary products, reference should be made to manufacturer's data for properties. Careful selection should be made in the case of these materials.
- b) Partial factors for non-metallic guys should be agreed between the designer, client and supplier.

**NA.2.37 Mechanical tests on ceramic insulating material [BS EN 1993-3-1:2006, D.3(6) Note 1]**

No additional information is provided.

**NA.2.38 Electrical properties of ceramic insulating material [BS EN 1993-3-1:2006, D.3(6) Note 2]**

The electrical properties, including allowance for static voltage from electrical storms, should be guaranteed by the manufacturer and confirmed by adequate type-tests, unless previous results are available.

**NA.2.39 Ladders, platforms, etc. [BS EN 1993-3-1:2006, D.4.1(1)]**

Further information is contained in PD 6695-3-1 and the International Association for Shell and Spatial Structures (IASS) Working Group 4 publication, "*Recommendations for safe systems for access on masts and towers*", September 2001 [2].

**NA.2.40 Lightning protection [BS EN 1993-3-1:2006, D.4.2(3)]**

Further guidance is given in PD 6695-3-1.

**NA.2.41 Aircraft warning [BS EN 1993-3-1:2006, D.4.3(1)]**

The marking and lighting of obstacles should be in accordance with:

- a) Civil Aviation Publication (CAP) 168 [3] for en route obstacles and those located on and in the vicinity of civil aerodromes; and
- b) Joint Services Publication (JSP) 554 [4] for obstacles located on and in the vicinity of government aerodromes.

Both documents are consistent with standards and recommended practices contained within ICAO Annex 14, Volume 1 [5].

**NA.2.42 Protection against vandalism  
[BS EN 1993-3-1:2006, D.4.4(1)]**

No additional information is provided.

**NA.2.43 Erection tolerances for towers  
[BS EN 1993-3-1:2006, F.4.2.1(1)]**

Annex F is not to be used (see PD 6695-3-1).

**NA.2.44 Erection tolerances for masts  
[BS EN 1993-3-1:2006, F.4.2.2(2)]**

Annex F is not to be used (see PD 6695-3-1).

**NA.2.45 Reduction factor,  $\eta$  [BS EN 1993-3-1:2006, G.1(3)]**

The recommended values of the reduction factor,  $\eta$ , for single angle members should be used.

**NA.2.46 Back to back angles [BS EN 1993-3-1:2006, H.2(5)]**

Where the maximum spacing of stitch bolts is greater than that specified in BS EN 1993-1-1:2005, 6.4.4, allowance for shear stiffness should be as follows.

- a) For buckling about the y-y axis (see BS EN 1993-3-1:2006, Figure 1.1) the two angles should be assumed to act compositely for the purpose of calculating stiffness and radius of gyration.
- b) For buckling about the z-z axis (see BS EN 1993-3-1:2006, Figure 1.1) the additional deformation due to shear should be taken into account by modifying the slenderness ratio,  $\lambda$ , in accordance with the following:

$$\lambda^2 = \lambda_0^2 + \lambda_1^2$$

where:

$\lambda_0$  is the slenderness ratio of the full compound member;

$\lambda_1$  is the slenderness ratio of one component angle ( $\lambda_1 = a/i_w$ );

$a$  is the length of the individual angle between stitch bolts.

In order to keep the effect of this interaction to a minimum, the spacing between stitch bolts,  $a$ , should be limited to give a maximum value  $\lambda_1$  of 90 or  $0,75 \lambda_0$ , whichever is the smaller.

When only stitch bolts and packs are used, composite section properties should be based on the smaller of:

- 1) the actual space between the individual angle members; or
- 2) a space taken as 1,5 times the minimum thickness of one of the angle members.

If batten plates are used in addition to stitch bolts,  $a$  should be taken as equal to the distance, centre-to-centre, of battens, and composite section properties may be used based on the actual space between the individual angle members.

*NOTE* When the two main components are connected so that the member is divided into only two bays, composite action cannot be assumed and the slenderness has to be based on the rectangular axis of a single component. Alternatively, a special analysis has to be undertaken to justify any composite behaviour.

#### NA.2.47 Design of battened and quadruple angle cruciform members [BS EN 1993-3-1:2006, H.2(7)]

Where the maximum spacing of stitch bolts is greater than that given in BS EN 1993-1-1:2005, 6.4.4, in addition to the provisions of BS EN 1993-3-1:2006, H.2(7), the additional deformation due to shear should be taken into account by modifying the slenderness ratio,  $\lambda$ , in accordance with the following:

$$\lambda^2 = \lambda_0^2 + \lambda_1^2$$

where:

$\lambda_0$  is the slenderness ratio of the full compound member.

$\lambda_1$  is the slenderness ratio of one component angle  $\lambda_1 = a/i_{vv}$ .

$a$  is the length of the individual angle between stitch bolts.

A method for determining the size of battens is given in Annex NA.3.

### NA.3 Decisions on the status of the informative annexes

#### NA.3.1 Modelling of meteorological actions [BS EN 1993-3-1:2006, Annex B]

BS EN 1993-3-1:2006, Annex B, as modified by NA.2.2 and NA.2.23 to NA.2.32, may be used.

#### NA.3.2 Ice loading and combinations of ice and wind [BS EN 1993-3-1:2006, Annex C]

BS EN 1993-3-1:2006, Annex C, as modified by NA.2.33 and NA.2.34, may be used.

#### NA.3.3 Guy rupture [BS EN 1993-3-1:2006, Annex E]

BS EN 1993-3-1:2006, Annex E may be used, with the following clarifications.

##### a) Simplified analytical model [BS EN 1993-3-1:2006, E.2]

The value of the horizontal force,  $H = F_{h,dyn,Sd}$  (see BS EN 1993-3-1:2006, Figure E.1), should be applied in the analysis of the mast without any guys present at the level of the ruptured guy.

*NOTE* The vertical component of the tensions in guys 2 and 3 ought to be included in the analysis

If guys 2 and 3 are included in the analysis,  $H$  should be taken as  $(F_{h,dyn,Sd} - F_{x,dyn})$ , where  $F_{x,dyn}$  is the value of  $F$  from curve 1 of BS EN 1993-3-1:2006, Figure E.2, at a displacement of  $U_{dyn}$ .

**b) Force-deflection [BS EN 1993-3-1:2006, Figure E.2]**

Curve 1 of BS EN 1993-3-1:2006, Figure E.2, may be produced from a non-linear cable analysis of guys 2 and 3 alone.

**c) Conservative procedure [BS EN 1993-3-1:2006, E.3(3)]**

The "resulting guy forces" refers to the additional force acting on the mast without the broken guy, as defined in BS EN 1993-3-1:2006, E.3(2).

**NA.3.4 Execution [BS EN 1993-3-1:2006, Annex F]**

BS EN 1993-3-1:2006, Annex F, should not be used (see PD 6695-3-1).

**NA.3.5 Buckling of components of masts and towers [BS EN 1993-3-1:2006, Annex G]**

BS EN 1993-3-1:2006, Annex G, as qualified by NA.2.45, may be used.

*NOTE* BS EN 1993-3-1:2006, G.2(b), states that values of the effective slenderness factor  $k$  may be determined from Table G.2 "in the absence of more accurate information".

*The factors given in BS EN 1993-3-1:2006, Table G.2, particularly for light tubular and rod members, as given in Table G.2(b), are critically dependent on the detailing adopted, the fabrication procedures (as recommended by PD 6695-3-1 and BS EN 1090-2) and the likelihood of extraneous loads being applied to such members during erection or in service. If there is any likelihood that adequate control in these matters cannot be achieved, higher values of  $k$  have to be considered and adopted.*

**NA.3.6 Annex H – Buckling length and slenderness of members [BS EN 1993-3-1:2006, Annex H]**

BS EN 1993-3-1:2006, Annex H, as modified by NA.2.46 and NA.2.47, may be used.

**NA.4 References to non-contradictory complementary information**

PD 6695-3-1, *Background paper to the UK National Annex to BS EN 1993-3-1* (in preparation)



## Annex NA.1 (Informative)

**Wind parameters for structures taller than 200 m****A.NA.1.1 General**

For structures taller than 200 m, wind parameters needed to assess the mean, gust and patch loads in accordance with BS EN 1993-3-1:2006, Annex B, and BS EN 1991-1-4 (together with its National Annex) should be obtained from **A.NA 1.2**.

**A.NA.1.2 Values of parameters**

Values for the following relevant parameters are given in Figures NA.3 to NA.8 of the IStructE website at <http://www.istructe.org/eurocodes/windukdata.asp>

Roughness factor,  $C_r(z)$ , is given in Figure NA.3.

Correction factor,  $C_{r,T}$ , is given in Figure NA.4.

Turbulence intensity,  $I_v(z)_{flat}$ , is given in Figure NA.5.

Turbulence correction factor,  $K_{I,T}$ , is given in Figure NA.6.

Exposure factor,  $C_e(z)$ , is given in Figure NA.7.

Exposure correction factor,  $C_{e,T}$ , is given in Figure NA.8.

## Annex NA 2 (informative)

**Parameter,  $k_s$** **A.NA.2.1 General**

The factor,  $k_s$ , is made up of three components as follows:

$$k_s = 3.7\lambda_B \lambda_R \lambda_{TL}$$

These components  $\lambda_B$ ,  $\lambda_R$  and  $\lambda_{TL}$  may be taken conservatively as:

$$\lambda_B = 0,75$$

$$\lambda_R = 1,2$$

$$\lambda_{TL} = 1,05$$

leading to:

$$k_s = 3,5$$

More accurate values for  $\lambda_B$ ,  $\lambda_R$  and  $\lambda_{TL}$  may be determined in accordance with **A.NA2.2**, **A.NA2.3** and **A.NA2.4**, depending on the load effect being considered.

**A.NA.2.2 Background scaling factor,  $\lambda_B$** 

The background scaling factor,  $\lambda_B$ , may be determined as follows:

— for midspan moments:

$$\lambda_B = 0,69\beta_s^{0,07}$$

— for deflections:

$$\lambda_B = 0,84\beta_s^{0,05}$$

— for shears and support moments:

$$\lambda_B = 0,70$$

where  $\beta_s$  is as defined in BS EN 1993-3-1:2006, **B.4.2(3)b**).

**A.NA.2.3 Resonant magnification factor,  $\lambda_R$** 

The resonant magnification factor,  $\lambda_R$ , may be determined as follows:

— for moments:

$$\lambda_R = 0,34Q + 0,91;$$

— for shears:

$$\lambda_R = 0,30Q + 0,92;$$

— for deflections:

$$\lambda_R = 0,16Q + 0,95$$

where  $Q$  is as defined in BS EN 1993-3-1:2006, **B.4.2(3)c**.

In all cases  $\lambda_R$  should be greater than or equal to 1.

**A.NA.2.4 Turbulent length scale factor,  $\lambda_{TL}$** 

The turbulent length scale factor,  $\lambda_{TL}$ , may be determined as follows:

— for midspan moments:

$$\lambda_{TL} = (h_s/L_U)^{0,135}$$

— for support moments:

$$\lambda_{TL} = 1,0$$

— for shears at midspan:

$$\lambda_{TL} = 1,0$$

— for shears at supports:

$$\lambda_{TL} = (h_s/L_U)^{-0,066}$$

— for deflection:

$$\lambda_{TL} = (h_s/L_U)^{-0,165}$$

where:

$h_s$  is the average span between adjacent guy levels (in m);

$L_U$  is the vertical length scale of along wind turbulence (in m) and is given by:

$$L_U = 3,1h_e^{0,55}(z_0)_e^{-0,1}$$

$h_e$  is the height above ground level of the area under consideration (in m) with a limiting value of 2 m;

$(z_0)_e$  is an effective terrain roughness length and is approximately given by:

$$(z_0)_e = 0,019 \ell_n(1,585 + x) \ell_n(1,41 + y)$$

where:

$x$  ( $\leq 100$  km) is the distance of the site from the sea (in km), measured in the direction of the wind;

$y$  ( $\leq 30$  km) is the distance of the site into town (in km), if relevant, measured in the direction of the wind and is taken as zero for sites in the country.

## Annex NA.3 (Normative)

**Design of battens**

**A.NA.3.1** The thickness of plate battens should be not less than  $1/50$  of the minimum distances between welds or fasteners. The slenderness of sections used as battens should not exceed 180. The width of an end batten along the axis of the main components should be not less than the distance between centroids of the main members and not less than half this distance for intermediate battens. Furthermore, the width of any batten should be not less than twice the least width of a main component.

**A.NA.3.2** The battens and the connections between them and the main components should be designed to carry the main forces and moments induced by a transverse shear at any point in the length of a member of not less than 2,5% of the maximum axial load in the member. For members carrying bending stresses calculated from eccentricity of loading, applied end moments or lateral loads, the battens should be proportioned to resist any shear due to bending in addition to the transverse shear value of not less than 2,5%.

**A.NA.3.3** Battens should be connected to the backs of angles parallel to both the rectangular axes of the members. They should alternate in each plane and the effective length of a main component should be taken as the spacing centre-to-centre of the battens in the same plane.

**A.NA.3.4** The transverse shear of not less than 2,5% of the axial load should be taken as acting perpendicular to the minor axis of the member. The battens in each plane should be designed for the components of this shear resolved perpendicular to the rectangular axes, plus any transverse shear due to the weight or wind resistance of the member.

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BS EN 1993-1-8:2005, *Eurocode 3: Design of steel structures – Part 1-8: Design of joints*

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<sup>1)</sup> Available from Forms and Publications (Sales), Defence Storage and Distributing Agency (DSDA), Building C 16 C Site, Lower Arcnott, Bicester, Oxfordshire OX 25 1LP. Tel: 01869 256052. Fax: 01869 256824. Email: formsandpubs@qcis.mod.uk



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